

AGM3F215

Figure 2-15.—(A) Normal refraction, (B) Subrefraction, (C) Superrefraction, (D) Ducting.

SUPERREFRACTION.—If the atmosphere's temperature increases with height (inversion) and/or the water vapor content decreases rapidly with height, the refractivity **gradient** will decrease from the standard (table 2-1). This situation is known as *superrefraction*, and causes the radar beam to deflect earthward below its normal path (fig. 2-15, view C). Generally, radar ranges are extended when superrefractive conditions exist. However, some targets may appear higher on radar than they would under standard atmospheric conditions.

Table 2-1.—Refractive Conditions as a Function of N-gradient

Refractive Condition	N-gradient
Ducting	≤ -48 N/thousand feet ≥ -157 N/thousand meters
Superrefractive	-48 to -24 N/kft -157 to -79 N/km
Standard	-24 to 0 N/kft -79 to 0 N/km

Superrefraction occurs under strong inversions, which are typical in subtropical, high-pressure zones.

DUCTING.—In extreme cases, a very rapid decrease in the N-gradient will cause radar waves to become trapped in a layer of the atmosphere and travel abnormally long distances (table 2-1). This phenomenon is known as *ducting* and is a frequent occurrence when strong inversions are present. When ducting occurs, a returning pulse may display low targets from hundreds of miles away—targets that are not normally detected (fig. 2-15, view D). This may cause an effect similar to range folding. False or exaggerated echoes are plotted where no meteorological targets exist. Keep in mind that ducting is also dependent upon the wavelength of the

radar. The larger the wavelength, the deeper the layer has to be before ducting can occur.

DIFFRACTION

Electromagnetic waves tend to follow along the curved surface of an object. Diffraction is the process that causes waves traveling in a straight path to bend around an object or obstruction. The direction of propagating energy is changed so that it spreads into a shadow zone, as shown in figure 2-16, view (A). In the earth-atmosphere system, diffraction occurs where the straight-line distance between the transmitter and receiver is just tangent to the earth's surface as shown figure 2-16, view (B). Generally, the lower the

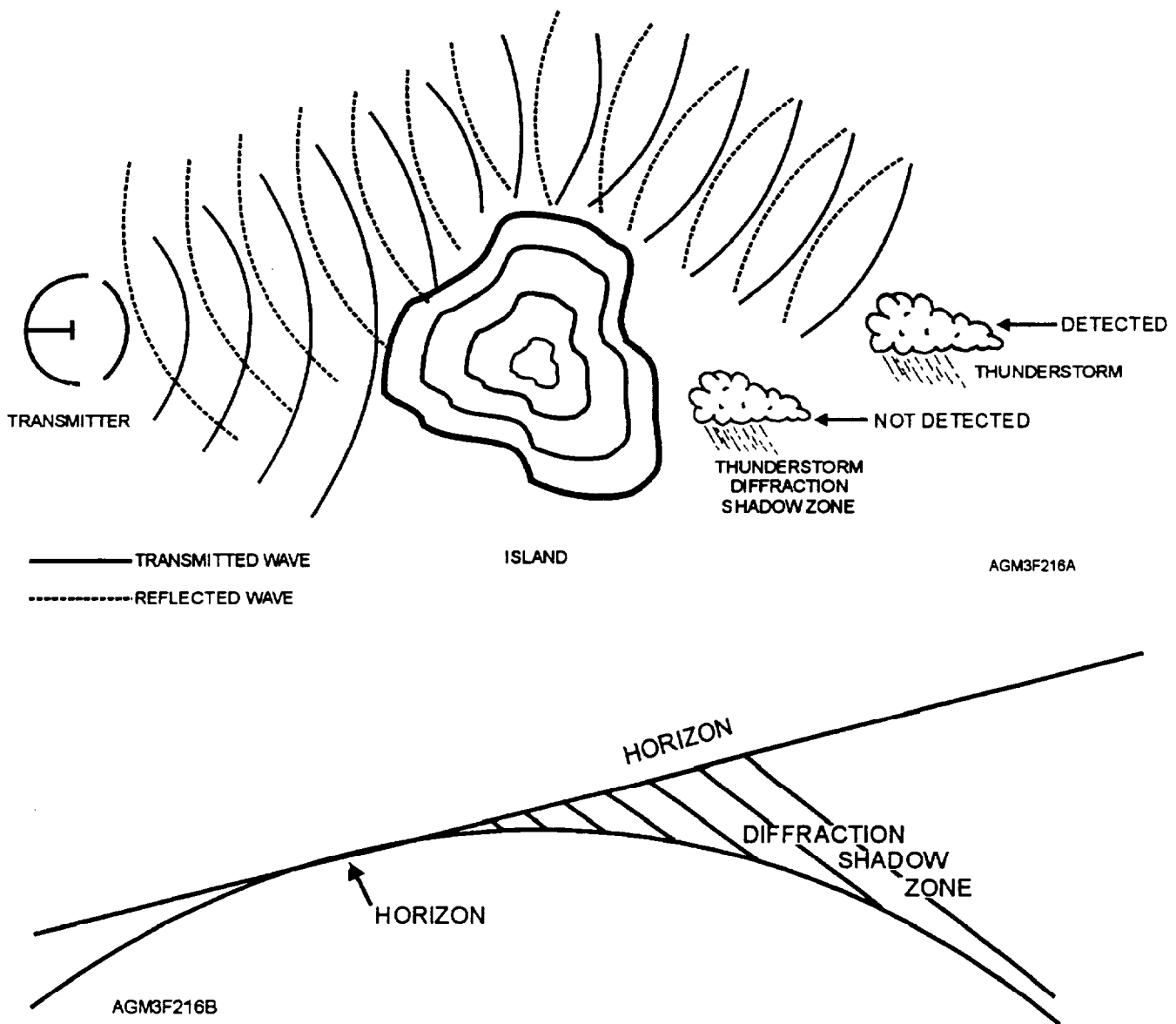


Figure 2-16.—(A) Diffraction of a radar wave front around an obstruction. (B) Radar horizon and diffraction region shadow zone.

frequency (longer wavelength), the more the electromagnetic wave is diffracted. Sidelobes are a direct result of diffraction occurring near the edges of a radar antenna.

GROUND CLUTTER

Another factor affecting radar performance is ground clutter. Ground clutter is an unavoidable form of radar contamination. It occurs when fixed objects, such as buildings, trees, or terrain, obstruct the radar beam and produce non-meteorological echoes. Echoes resulting from ground clutter are usually exaggerated in both size and intensity and may cause radar systems to overestimate precipitation intensity near the radar.

Clutter is normally found close to the antenna where the radar beam is nearest to the ground. Further out, the beam points gently skyward and overshoots most obstacles. Under certain circumstances, however, clutter may exist far away. A tall mountain range would be a good example of this. The key to dealing with ground clutter is operator awareness and experience.

OTHER FACTORS AFFECTING EM ENERGY

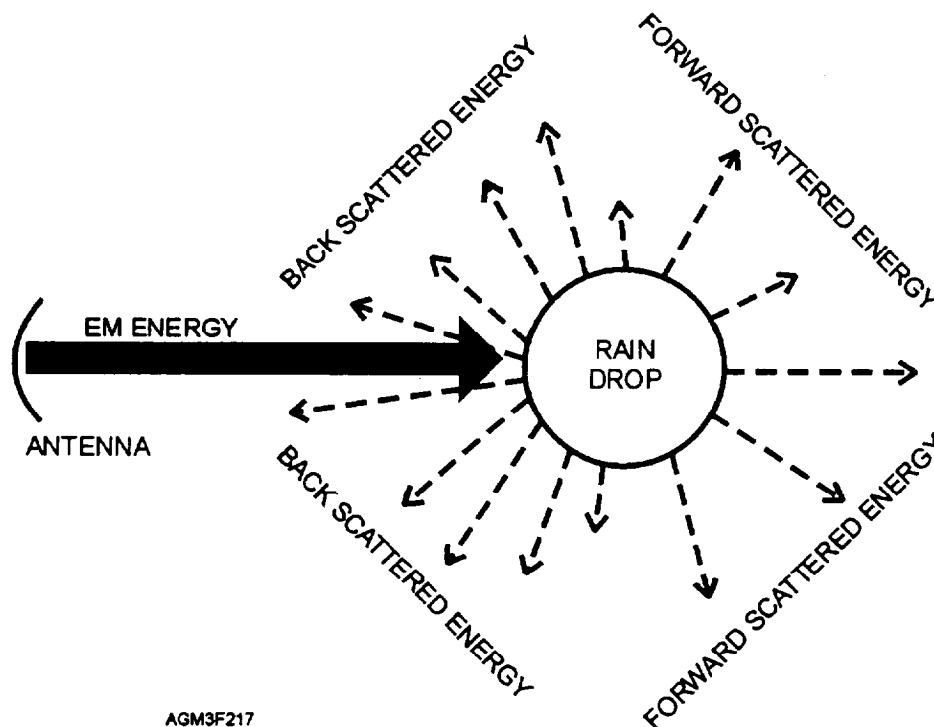
As energy travels through space, it interacts with millions of scatterers. This interaction causes a significant amount of energy to be lost or *attenuated*.

Attenuation occurs in the form of scattering or absorption, but in either case, it reduces radar performance. The degree of attenuation is dependent on several factors, particularly radar frequency and atmospheric water vapor content.

Scattering

Scattering occurs when energy strikes a target and is deflected in all directions (fig. 2-17). Forward scattering is re-radiation of energy away from the antenna, and all of this energy is permanently lost to the radar. Not all forms of scattering are attenuation. *Backscattering*, for example, occurs when energy is reflected back toward the antenna resulting in a net gain. Larger targets tend to backscatter significantly more energy than smaller ones do, and therefore, result in stronger returns. Without backscattering, no targets would be detected and no echoes would be plotted. The bottom line is that scattering may or may not be attenuation. The type and amount of scattering present determines radar performance.

The degree of scattering is not only dependent on particle size and composition, but also wavelength. Wavelengths used in weather radar are selected to minimize scattering by particles smaller than the radar was designed to detect (i.e. clouds and precipitation).



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Figure 2-17.—Scattering of radar energy.

Absorption

The atmosphere absorbs some amount of EM energy, mainly by oxygen and water vapor. It becomes trapped within these parcels long enough to become unrecognizable to the radar. Absorption, like any form of attenuation, results in lost power and decreased radar performance. Like scattering, the degree of absorption is dependent on particle size, particle composition, and wavelength. The longer the wavelength, the smaller the attenuation due to absorption.

Solar Effects

Due to the high sensitivity of the WSR-88D, anomalous returns near sunrise or sunset may occur. These false returns are generated because the sun radiates energy in the same region of the electromagnetic spectrum as the WSR-88D. These echoes are recognized by their continuous, narrow "baseball bat" appearance.

REVIEW QUESTIONS

- Q25. *What is refraction?*
- Q26. *What atmospheric parameter has the greatest impact on refraction and refractivity?*
- Q27. *What normally happens to N-units with increasing altitude?*
- Q28. *If a radar beam is consistently overshooting targets, which refractive condition might be present?*
- Q29. *The phenomenon of ducting is most likely to occur under what atmospheric condition?*
- Q30. *What is the cause of ground clutter?*
- Q31. *What type of scattering is NOT attenuation?*
- Q32. *What are the main absorbers of EM energy in the atmosphere?*

PRINCIPLES OF DOPPLER RADAR

LEARNING OBJECTIVES: Define Doppler and Doppler shift. Define phase shift and radial velocity. Recognize the effects of target motion on radial velocity. Define velocity aliasing. Recognize the effects of velocity aliasing on Doppler radar. Compute Nyquist velocity. Identify Doppler dilemma.

So far, we have discussed basic principles of electromagnetic energy common to all radar systems. The following text expands on the theory and principles already discussed and introduces concepts unique to Doppler radar.

Doppler is a means to measure motion. Doppler radars not only detect and measure the power received from a target, they also measure the motion of the target toward or away from the radar. Although Doppler radar enjoyed widespread use for many years, cost made it an impractical tool for weather detection. Only recently has expense been offset by the technological breakthroughs of the Doppler meteorological radar, WSR-88D. This shore-based radar has capabilities that far exceed those of older Doppler systems. These capabilities include a complementary mix of **velocity** detection, increased power and sensitivity, and the integration of high tech computers. This automation provides forecasters with a wealth of information. The WSR-88D not only can detect target motion and velocity, but can also examine internal storm circulations as well as detect atmospheric motions in clear air.

The WSR-88D excels in detecting severe weather events, and more important, increases advance warning time. In addition, the increased sensitivity of the WSR-88D allows various meteorological boundaries to be identified. These boundaries include synoptic fronts, gust fronts, drylines, land and sea breeze fronts, and thunderstorm outflows.

DOPPLER SHIFT

In 1842, the Austrian physicist Johann Christian Doppler first related motion to frequency changes in light and sound. Doppler discovered that the shift in frequency caused by moving sources of sound was directly proportional to the speed of the source. He then developed mathematical formulas to describe this effect called the *Doppler Shift*. While not given much thought, you experience Doppler shifts many times each day. The change in pitch of a passing train whistle and a speeding automobile horn demonstrate its effects. When you hear a train or automobile, you can determine its approximate location and movement.

Doppler radar accomplishes much the same thing, but to a higher degree of accuracy. As a target moves toward a radar, frequency is increased; if the target is moving away from a radar, the frequency is reduced. The radar then compares the received signal with the frequency of the transmitted signal and measures the

frequency shift, giving the motion and speed of the target.

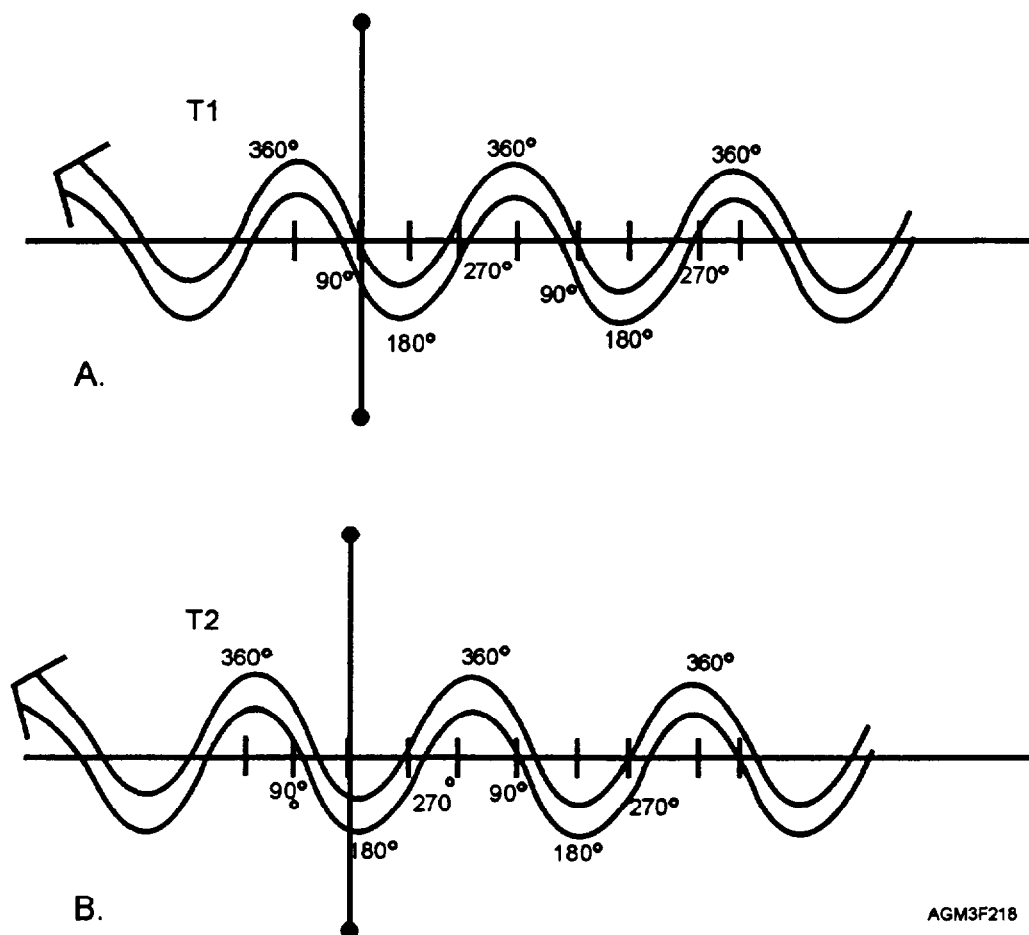
While frequency of electromagnetic energy is modified by moving targets, the change is usually too slight to measure precisely. Therefore, Doppler radar focuses on the **phase** of electromagnetic energy, as this aspect experiences a greater degree of displacement and increases the likelihood of detecting motion. Using phase shifts instead of frequency changes can be compared to viewing an insect under a magnifying glass. Features that might otherwise go unseen take on a new dimension and become observable.

PHASE SHIFT

The phase of a wave is a specific point or benchmark along that wave. A *phase shift* is an observable repositioning of this benchmark between successive transmissions. A pulse Doppler radar, in its simplest form, provides a reference signal by which

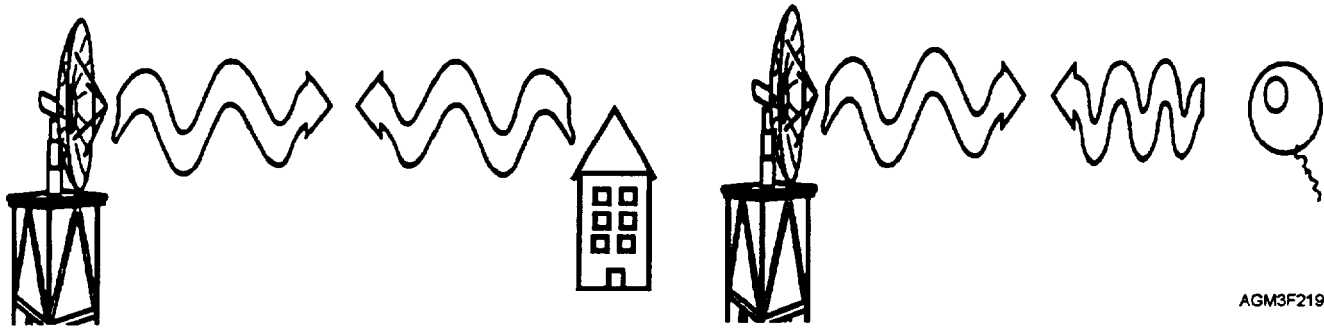
changes in the frequency phase of successively received pulses may be recognized. The known phase of the transmitted signal allows measurement of the phase of the received signal. The Doppler shift associated with the echo from which the return originated is calculated from the time rate of change of phase.

The phase of a wave, measured in degrees, where 360 degrees equals one wavelength, indicates the current position of the wave relative to a reference position. For example, look at figure 2-18. At time T1 (fig. 2-18, view A), the position of the wave along the vertical line was as shown, while at time T2 (fig. 2-18, view B), the position of the wave along the vertical line was as shown. Notice that the wavelength did not change from T1 to T2. However, the wave's position relative to the vertical line changed 1/4 wavelength, or 90 degrees. This change is the phase shift.



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Figure 2-18.—Wavelengths and phase shifts. (A) T-1 is wave reference position. (B) T-2 wave's position has changed 90° from reference position (T-1).



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Figure 2-19.—(A) Stationary target causing no visible change in wave characteristics, (B) Moving target displacing energy causing observable phase shifts.

As another example, look at figure 2-19, view (A). Imagine a Doppler radar repeatedly striking a stationary target such as a building. Since the speed at which energy travels is constant, each wave returns in exactly the same phase as those before it. Now look at figure 2-19, view (B). Consider a large balloon moving slowly toward the antenna. Unlike the stationary building, the balloon's motion causes a change in the appearance of each successive wave. If the radar observes these changes (phase shifts) it will realize that motion has occurred and can then convert this information into target **velocity**. Keep in mind that the ability of a Doppler radar to detect phase shifts and compute velocity depends upon the system maintaining a consistent transmitter frequency and phase relationship from one pulse to the next.

RADIAL VELOCITY

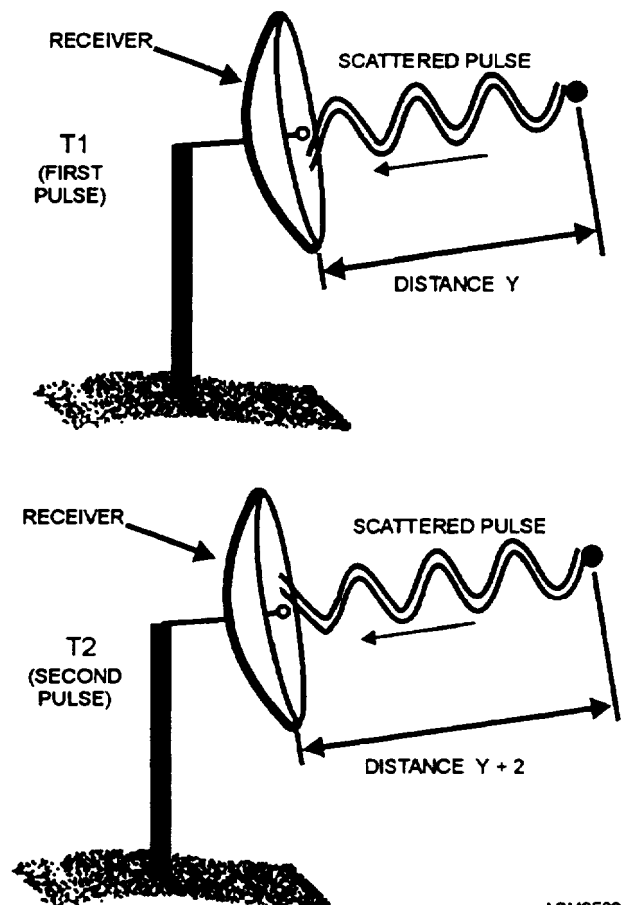
We know that Doppler radars can tell whether a target is moving toward or away from the radar. Doppler radars can also measure the velocity of the target toward or away from the antenna. Take a look at figure 2-20. At time T1 a pulse is sent towards a target and it returns at target distance "Y." At time T2, another pulse is sent towards the same target and returns a target distance of "Y+Z." The distance to the target has changed from time T1 to T2, resulting in a phase shift between the two return signals. By measuring the **phase shift**, the **wavelength**, and the **time interval** from T1 to T2, the velocity the target moved toward or away from the radar can be computed.

By convention, motion **towards** a Doppler radar is expressed in **negative** values and green (cool) colors on a display screen. Motion **away** from a Doppler radar is expressed in **positive** values and red (warm) colors.

The WSR-88D's sensitivity enables it to detect extremely weak reflectivities (light drizzle, ice

crystals, etc.). This sensitivity allows the radar to determine the wind speed from the size of the phase shift. Even dust or insects can act as scatterers and enable the WSR-88D to determine wind speeds in clear air.

The WSR-88D will not always detect every motion in the atmosphere, nor will it display them with little or no confusion. Since only pulsed energy that returns directly to the antenna can be detected, it stands to reason that phase shifts are only observable when they occur directly along the radar beam (radial).



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Figure 2-20.—Radial velocity.

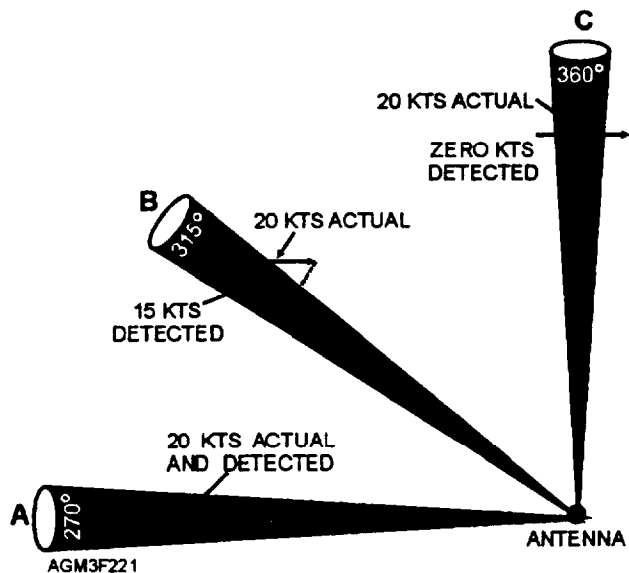


Figure 2-21.—Affects of return component on radial velocity.

Thus, Doppler radars can only measure the component of a target's motion that occurs along the radial axis. This component is called the *radial velocity*.

Motion Parallel Along Radial Axis

If a parcel moves directly toward or away from the antenna, we say its motion is parallel to the radial axis (beam). Truly parallel motions allow the phase shift of each wave to become fully visible to the radar. The result is that displayed velocities reflect the parcel's true speed. In figure 2-21 (component A), the wind is blowing from the west at 20 knots, and the antenna is pointing toward 270°. The WSR-88D views the full component and measures all 20 knots.

Motion Diagonally Across Radial Axis

When a parcel's motion becomes diagonal to the radial axis, only some portion of its phase shift is observed. Since less than maximum motion is realized, an underestimation of target speed is plotted and displayed. The degree of error depends entirely on the parcel's angle and orientation. In figure 2-21 (component B), the wind is still blowing from the west at 20 knots, but the antenna is pointing toward 315°. Only a portion of the wind is blowing directly toward the antenna and the WSR-88D measures only 15 knots.

Motion Perpendicular to Radial Axis

Since the radar antenna rotates in a full circle (360°), the parcel's orientation (to the beam axis) is ever changing. At some point, the parcel's motion becomes perpendicular to the radial and exhibits **zero motion** toward or away from the antenna (fig. 2-21, component C). This does not necessarily mean that the target is stationary. It simply means that the target is remaining at a constant distance from the radar and because of the radar's perpendicular viewing angle, no phase shift is observed. As far as the radar is concerned, the return pulse remains unchanged and no phase shift has occurred. From this information, the parcel is considered stationary. Zero velocity is displayed while the parcel's actual speed goes undetected. In the following text, we will show how the WSR-88D deals with this problem.

VELOCITY ALIASING

Imagine two trains connected back-to-back. Since trains have the unique ability to go full speed in either direction, their orientation poses no problem. Notice the method that trains use to display speed (fig. 2-22).

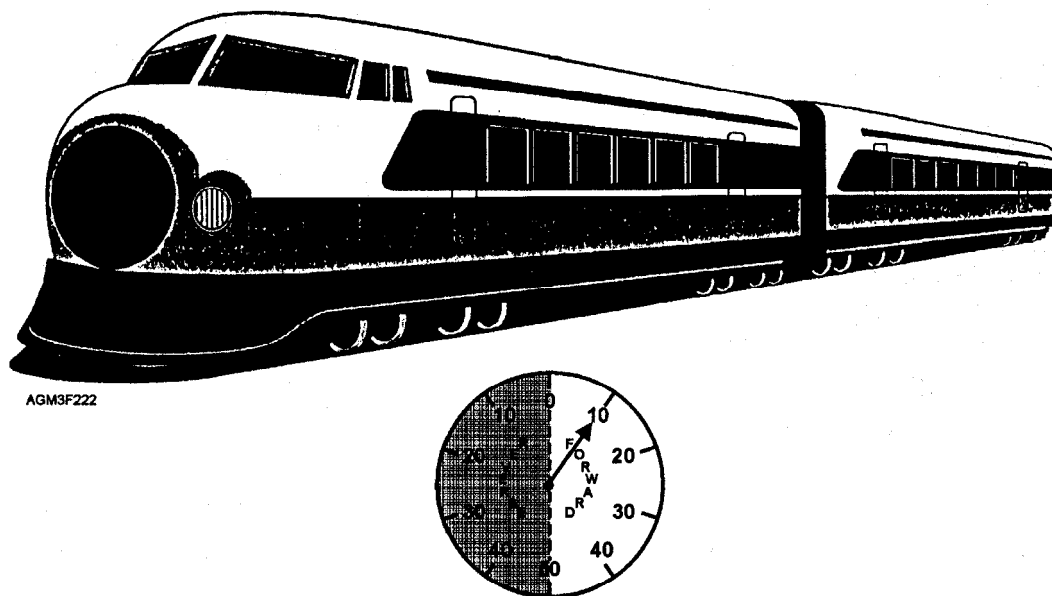


Figure 2-22.—Train speedometer.

Forward speeds are on the right half of the speedometer, while reverse speeds are on the left. Speeds of less than 50 mph are clear-cut (unambiguous), and cause no confusion. However, speeds of 50 mph or more are ambiguous and cause a phenomenon known as velocity aliasing. *Velocity aliasing* is a process that causes a Doppler radar to display untrue velocity values because of the motion of the target.

Consider the following scenario. A train departs the station traveling forward at 40 mph (fig. 2-23, view A). Beyond city limits, its cruising speed is increased another 20 mph (fig. 2-23, view B). Suddenly something is wrong! The speedometer reads 40 mph in reverse. The train did not change direction; it has simply exceeded the limits of its instrument. The train's speed appears aliased as 40 mph *in reverse*, obviously an **ambiguous** velocity.

While radars don't use speedometers, they do measure phase shifts and experience velocity aliasing in much the same way as the train. Consider the 360° of one wavelength as the radar's speedometer. When phase shifts are less than 180° (one-half wavelength), they are clearly detectable. However, shifts of 180° or more are ambiguous. The radar is unsure if motion is inbound toward the antenna at 60 knots, or outbound at 40 knots.

Look at figure 2-24. In views (A) and (B), the target's motion poses no problem to the radar as both motions produce phase shifts of less than 180° (one-half wavelength), regardless of direction. Illustration (C) depicts a phase shift of 180° . Here is where the

problems begin. Remember, that to unambiguously measure the phase shift, the shift must be less than one-half the wavelength (180°). In this case, we cannot distinguish whether the 180° shift represents motion toward or away from the radar. This measurement is ambiguous. Illustration (D) depicts a phase shift of 270° resulting from energy striking a target that is moving away from the radar. Since a shift of 270° is more than one-half wavelength (180°), it is ambiguous. This 270° shift is seen as a 90° phase shift of motion **toward** the radar. This can result in an aliased velocity being displayed.

While aliased velocities are subject to misinterpretation, the WSR-88D has a unique way of dealing with them. Computer programs are designed to recognize that direction reversal is impossible. They determine that wind speeds are exceeding radar tolerance and calculate the amount of aliasing occurring. All necessary corrections are then applied to the products you receive.

Nyquist Velocity

As just explained, velocity detection is wavelength dependent. As soon as the one-half wavelength limit is passed, the determination of velocity becomes ambiguous. Anytime we speak of wavelength, the same arguments hold for frequency, since they are inversely related. Ultimately, the pulse repetition frequency (PRF) of a radar determines the maximum speed that can be detected without confusion. The maximum unambiguous velocity that can be detected at a given PRF is called the *Nyquist velocity*. Nyquist

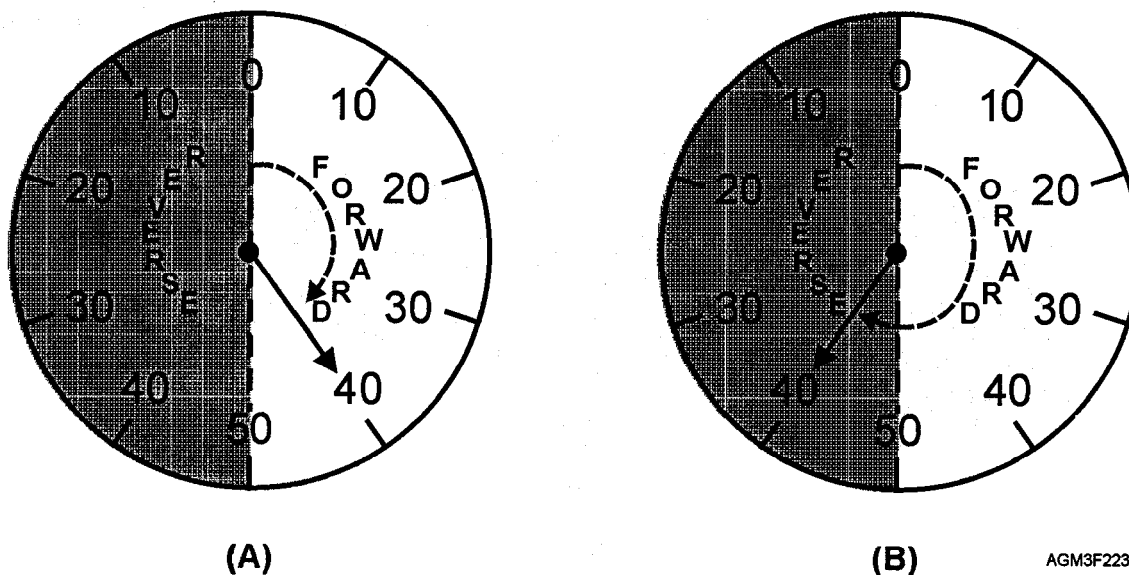


Figure 2-23.—(A) Speedometer showing true velocity. (B) Speedometer showing ambiguous velocity.

— = TRANSMITTED ENERGY
 - - - = RECEIVED ENERGY

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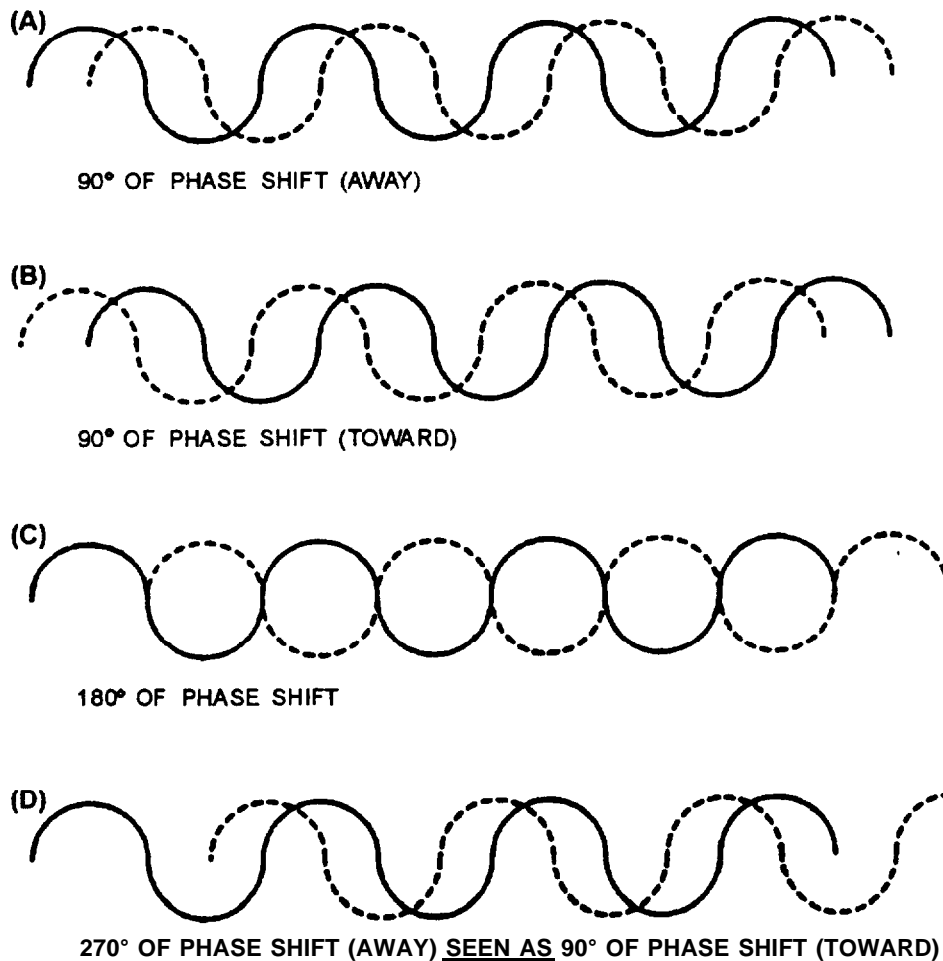


Figure 2-24.—Several phase shifts. (A) 90° of phase shift (away), (B) 90° of phase shift (toward), (C) 180° of phase shift, (D) 270° of phase shift (away) SEEN AS 90° of phase shift (toward).

intervals are those velocities from zero up to and including the Nyquist velocity. The Nyquist co-interval is the entire range of detectable velocities both negative and positive. For example, if the Nyquist velocity is 25 knots, then the Nyquist interval is any velocity from 0-25 knots, and the Nyquist co-interval is -25 through +25 knots.

Since the WSR-88D has a fixed wavelength of 10.7 cm, we can compute the Nyquist velocity (V_{\max}) for any given PRF from the following formula: $V_{\max} = (\text{PRF}) \times (\text{Wavelength}) \div 4$. For example, a WSR-88D radar operating with a PRF of 1000 would have a Nyquist velocity of 52 knots. This is found by multiplying 1000 by 10.7 and dividing by four (2675 cm/sec). This can then be converted to 26.75 meters per second (100 centimeters in a meter). Multiply this value by 1.94 to convert to knots. From this formula, you can see that higher PRFs yield higher maximum

detectable velocities, and that lower PRFs will increase the chances of velocity aliasing.

Doppler Dilemma

We learned earlier that Doppler radar is subject to range folding. This resulted when the radar detected a previous pulse while listening for the most recent pulse. Reducing the pulse repetition frequency (PRF) and allowing for a longer listening time will alleviate the problem of range folding. However, as just discussed, low PRFs may then lead to the problem of velocity aliasing. These two difficulties combine to define what is known as the *Doppler dilemma*. For example, in order for the WSR-88D to detect radial velocities of 200 mph without aliasing, the PRF would have to be increased to about 4,000 pulses per second. However, this would reduce the maximum unambiguous range of the radar to about 20 nmi. To have an unambiguous range of 100 nmi, the PRF would

have to be approximately 810 pulses per second. This would cause the maximum unambiguous velocity to decrease to 45 mph.

The Doppler Dilemma is caused by physical restrictions based on the laws of nature. One of the ways the WSR-88D works around this dilemma is to operate at variable PRFs, collecting reflectivity information at low PRFs and velocity information at high PRFs. The two sets of information collected are compared and processed to estimate true radial velocities and ranges.

Range Versus Height

The WSR-88D samples through 360° at a series of fixed elevation angles. At each elevation angle, the distance outward along the radar beam represents an increase in height above the ground. In other words, the further you move away from the antenna, the higher the beam is off the ground. You must remember that the very center of a product display represents only the height of the radar tower, while the outer edges of the display are thousands of feet above the ground. You can now see how the WSR-88D gives you a pseudo three-dimensional display.

REVIEW QUESTIONS

- Q33. *Doppler is used to measure what property?*
- Q34. *What are some of the advantages of the WSR-88D over conventional weather radars?*
- Q35. *What happens to a return frequency when a target moves toward a radar?*
- Q36. *What is a "phase shift"?*
- Q37. *The phase of a wave is measured in what units?*
- Q38. *Which three measurements are required to compute radial velocity?*
- Q39. *How is the detected velocity of a target affected as the target moves more perpendicular to a Doppler radar antenna?*
- Q40. *What is "velocity aliasing"?*
- Q41. *What is meant by the term "Nyquist velocity"?*
- Q42. *What would be the Nyquist velocity of a WSR-88D radar operating with a pulse repetition frequency (PRF) of 1100?*
- Q43. *The "Doppler dilemma" is a combination of what two difficulties?*

WSR-88D SYSTEM FUNDAMENTALS

LEARNING OBJECTIVES: Identify the major components of the WSR-88D. Identify the purpose of the RDA, RPG, UCP, and PUP. Recognize the various WSR-88D system users and their capabilities. Distinguish between wideband and narrowband communication links. Recognize the basic configuration of the National Weather Radar Network. Identify the various data archive levels. Identify the major volume coverage patterns of the WSR-88D.

The following text provides an overview of the WSR-88D system layout, communication configuration, and data flow. The WSR-88D is much more than just a radar—it is actually a carefully integrated system of basic radar components, sophisticated computer hardware and software, and a unique communications network. Minimum system configuration includes four major components: an RDA (Radar Data Acquisition), an RPG (Radar Product Generator), a UCP (Unit Control Position) and a PUP (Principal User Processor). While these components might be separated by many miles, they remain linked to each other through an intricate communication network (fig. 2-25).

RADAR DATA ACQUISITION (RDA)

The RDA consists of an antenna and all subcomponents necessary to process backscattered (reflected) energy into useful radar information. The RDA is considered to be the radar's eyes and ears because it provides a detailed snapshot of the radar's surrounding environment. It strategically scans thousands of square miles, and controls transmission and receipt of all radar energy. Any accumulation of data is then passed on to the RPG for in-depth analysis.

Radar Moments

Since all atmospheric scatterers provide valuable information, the ability to see them is useful in forecasting, observing, and warning weather customers. Obviously we want to see as many of these scatterers as possible. The RDA is responsible for this detection process. The RDA performs signal processing of Doppler weather radar data and transfers this data based upon three radar moments. A radar moment is a measurement of a scatterer's reflectivity, velocity, and/or spectrum width at a specific period in time.

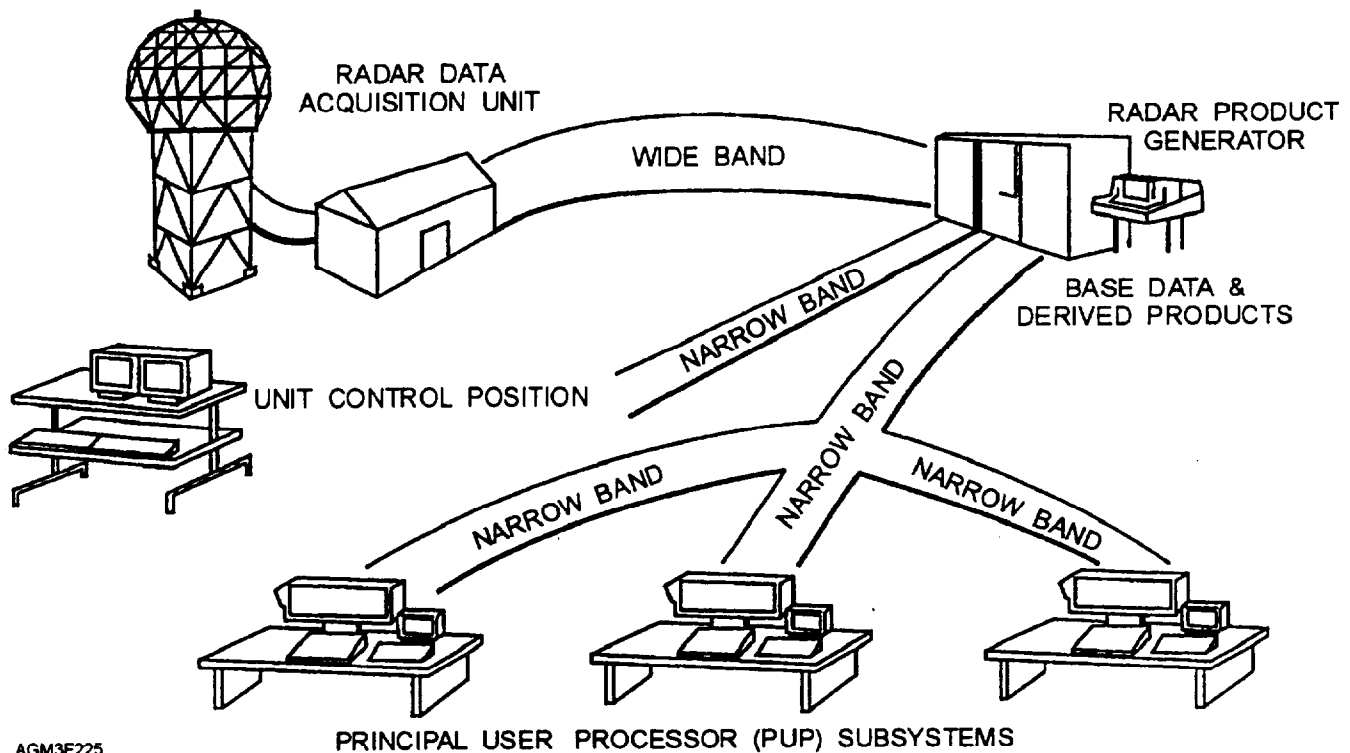


Figure 2-25.—WSR-88D system configuration.

REFLECTIVITY.—Recall, some degree of energy is likely to be returned to the antenna as a result of backscattering, and that size, shape, and composition all contribute to a target's ability to backscatter this energy. Stronger targets have higher levels of reflectivity and return more energy. Thus, stronger targets have higher reflectivity values; that is, higher dBZ levels. For example, large raindrops backscatter many times more power than drizzle and will produce reflectivity levels 5 to 10 dBZ higher. Because of its characteristics, hail tends to have exceptionally high reflectivity values. And, since the WSR-88D displays information in the form of echo intensity levels, a severe thunderstorm with hail will appear much more intense than an area of light rain or drizzle.

VELOCITY.—Velocity is used to determine wind speed, direction, and target motion (perhaps the movement of a thunderstorm cell). The WSR-88D can detect small areas of convergence, divergence, and even circulation. This has proven valuable in alerting whole communities to the onset of strong surface winds and tornadic activity.

SPECTRUM WIDTH.—Spectrum width data is another method of determining atmospheric motion. Spectrum width examines the degree of velocity

variance of particles (scatterers) in the atmosphere that results from dispersion and mixing. Within a single sample volume of the atmosphere, many particles of varying size, shape, and composition move in different directions and speeds. Because of their differences, each particle moves about independently of the others. Within this single sample volume, the WSR-88D does not sense each individual motion, but rather a combination of all velocities for the overall sample. This combination of different velocities is what spectrum width measures.

Spectrum width data is quite useful in determining atmospheric stability, and is a good indicator of environmental turbulence. By itself, it offers very little guidance. Combined with other products, the user can determine radar performance and reliability of the data being displayed. The concept of evaluating spectrum width data is still relatively new and operational uses are still being developed.

RDA Subcomponents

The RDA consists of all the hardware and software needed to transmit and receive radar energy. It also preprocesses raw data by filtering inconsistencies. The transmitter, receiver, and signal processor are housed together in a small building near the antenna, as

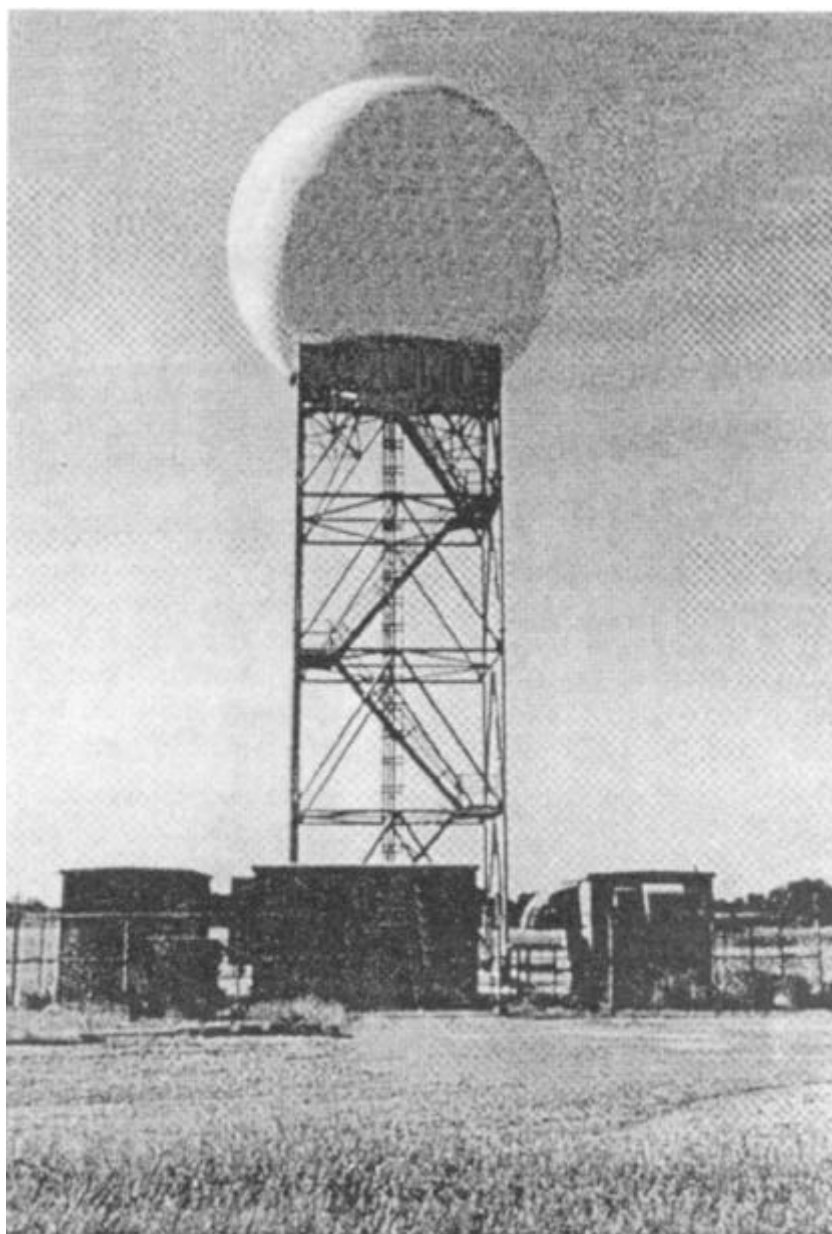
pictured in figure 2-26. These components, together with the antenna, make up the RDA. Only a single RDA exists for each system.

ANTENNA.—The WSR-88D uses a 28-ft dish-shaped antenna to focus radar energy along a concentrated beam. This same antenna is used to receive backscattered energy from targets and atmospheric scatterers.

PEDESTAL.—A cast aluminum structure that secures the antenna to the top of a 98-ft steel tower. The

pedestal controls antenna movement with pinpoint accuracy. It rotates the antenna continuously at a maximum speed of 5 revolutions per minute and automatically changes elevation angles in predetermined increments.

RADOME.—A spherical cover that protects the antenna. Made of rigid fiberglass, the radome measures about 39 ft in diameter and resembles a giant golf ball. Its design inhibits ice and snow buildup. Figure 2-27 shows the antenna, pedestal, and radome.



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Figure 2-26.—WSR-88D Radar Data Acquisition (RDA).

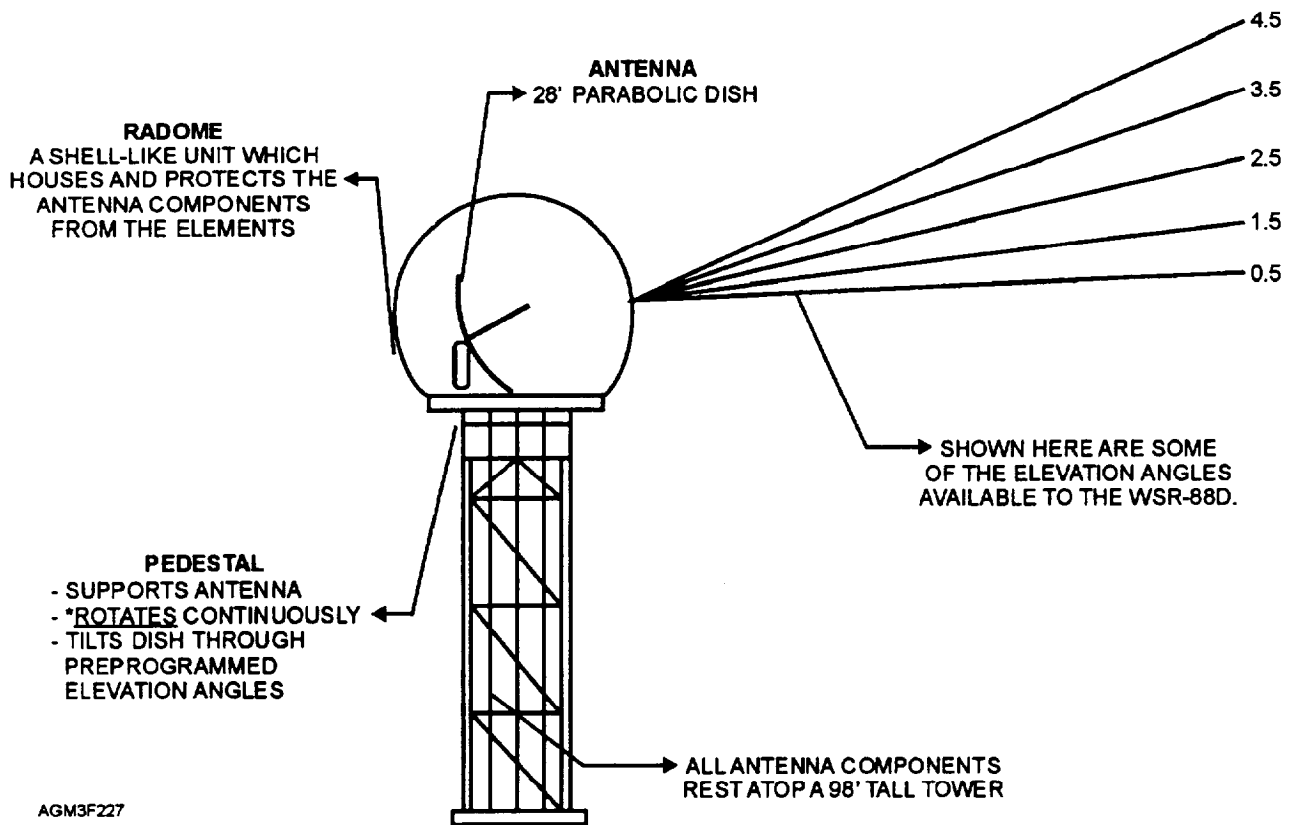


Figure 2-27.—WSR-88D antenna, pedestal, and radome.

TRANSMITTER.—The transmitter is an amplifier that generates high-powered pulses which are then radiated by the antenna. By producing nearly triple the power of earlier radars, the transmitter is the driving force behind the WSR-88D sensitivity. The transmitter has an operating frequency range of 2,700 to 3,000 MHz (2.7 to 3.0 GHz).

RECEIVER.—Backscattered energy generally travels many miles before returning at a fraction of its original strength. This makes it difficult to interpret. Much like a stethoscope helps a doctor hear sounds from deep within your chest, the receiver boosts signal strength of backscattered energy to levels at which the radar can extract crucial target information. Amplified energy is then routed to the signal processor.

SIGNAL PROCESSOR.—The signal processor is the first of four computers within the WSR-88D to encounter radar data. Here, data coming from the receiver is digitized, and contaminants, such as range folding and ground clutter, are reduced or eliminated. This preprocessing converts raw (analog) data into a digitized "base data" format.

RDA Special Processes

The significance of range folding and ground clutter were discussed earlier in this chapter. Two special features of the RDA signal processor include a range **unfolding** process and a ground clutter filtering process.

RANGE UNFOLDING.—The process of cleaning up range folded data must begin by comparing each echo to previous scans. If continuity exists for an echo, the target is considered real and the test is terminated. However, if an echo has mysteriously appeared with no prior history, a secondary test is performed. In such cases, the signal processor compares mystery echoes to energy received from beyond the radar's displayable range. Through pattern matching, it determines the likelihood of each target's true existence, or the probability that such targets are a result of range folded data. If range folding is confirmed, false echoes are removed from products. If the processor is unsure, suspect areas are shaded purple. This purple area is easily recognized and alerts you to the possibility of range folding. When preprocessing is complete, data is transmitted to the RPG.

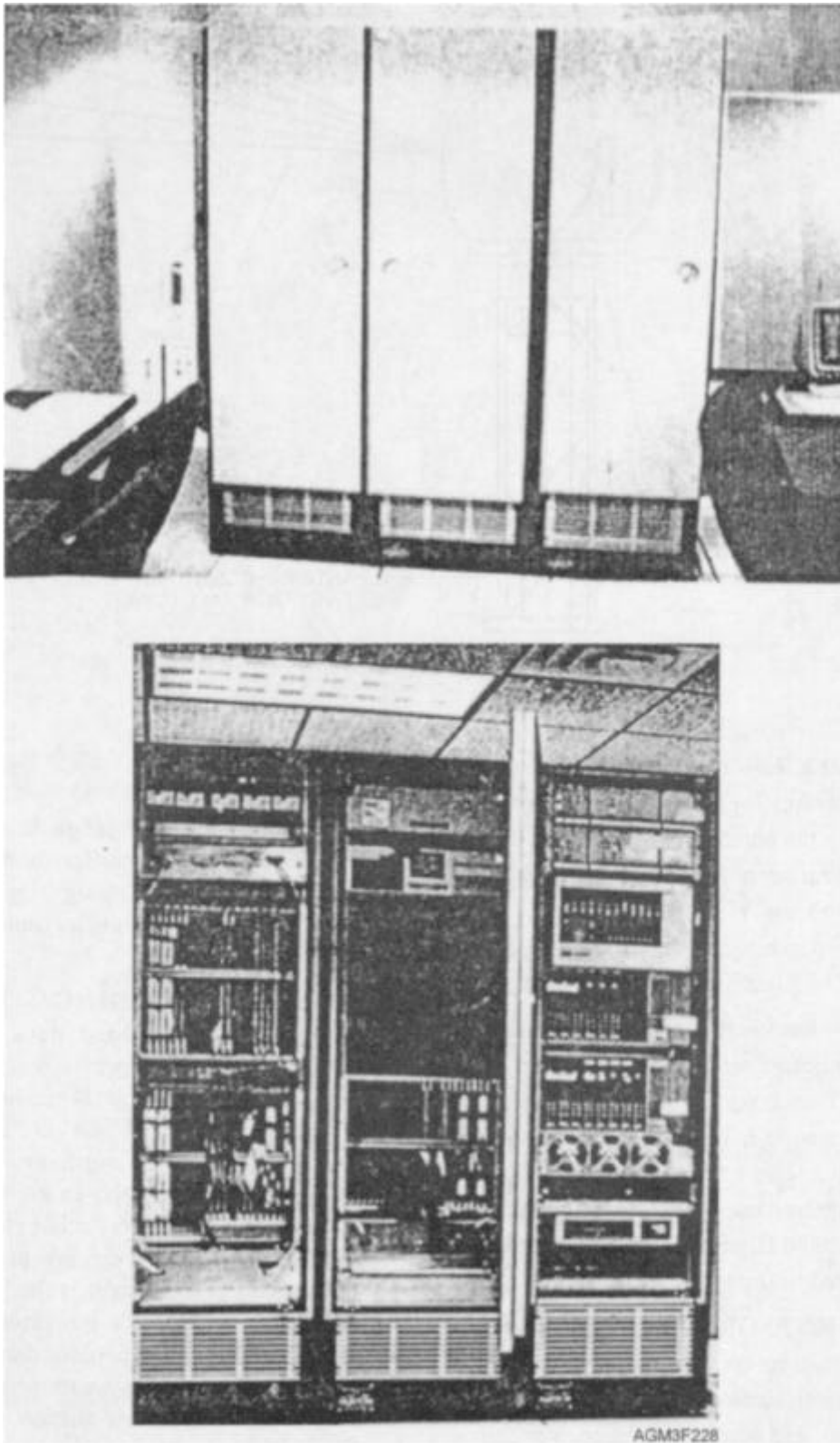


Figure 2-28.—WSR-88D Radar Product Generator (RPG).

GROUND CLUTTER FILTERING.—The process of reducing the effects of ground clutter begins as the data (radar returns received at the RDA) leaves the RDA's signal processor. A ground clutter suppression algorithm is then applied. This algorithm is designed to suppress power (reduce reflectivity) from echoes that return a lot of energy but are not moving (buildings, trees etc.). Two clutter suppression maps are created during this process: one map is used by the RDA to determine which echoes are of a permanent nature (buildings, trees), and a second map that is used by the operator to select areas for specific clutter suppression. Once built, these maps can be referenced by the radar to apply suppression to clutter that has been identified with each new scan of the radar. Obviously, this process increases product reliability.

RADAR PRODUCT GENERATOR (RPG)

The RPG is considered the "brains" of the WSR-88D. It is a bulky mainframe computer, housed in what resembles an oversized wall locker (fig. 2-28). An alphanumeric input terminal allows user interface. The RPG creates all WSR-88D radar products by performing sophisticated analyses of data through a multitude of computer programs called *algorithms*. The RPG provides hundreds of new and unique products every 5 to 10 minutes. Because of the vast quantities available, products themselves are categorized as either base or derived products. **Base** products are near real-time images. They display targets as seen by the radar during its most recent scan. **Derived** products, on the other hand, are specialty products. Derived products evolve from base products that have been modified or enhanced to produce special results. Derived products are often used specifically to examine features that are not easily seen on base products. We will discuss the more important base and derived products later.

Once products are built, the RPG stores and distributes them according to predefined system commands. In some cases the RPG is instructed to generate audible alarms (alerts) when special weather conditions are detected. Once alerted, users may examine conditions more thoroughly by using all available products. Conditions that trigger these alerts are user definable and can be tailored to meet the mission of your base. Strong wind velocities, rotational shear, or intense reflectivity values (from

thunderstorms) are among the more popular criteria used to trigger alerts.

The RPG may be located many miles from the RDA, but remains critical to the production process. Without it, NO radar products are available. It is important to mention the links that exist between these components. Considering the volume of data collected, the communications link between the RPG and RDA is crucial. Without it, the system is non-functional. For this reason, the RDA and RPG are connected via a "wideband" communications link, which acts as an information superhighway on which massive volumes of data can flow freely (refer to fig. 2-25). Like the RDA, only a single RPG exists for each WSR-88D system. It supports all users who subscribe for products of that system.

PRINCIPAL USER PROCESSOR (PUP)

Up to this point we've discussed the RDA (which transmits and receives radar energy) and the RPG (which builds products from that energy). Now let's discuss how you will gain access to these products. The PUP is a sophisticated computer workstation that allows human interface with the WSR-88D (fig. 2-29). Here, the observer or forecaster can display or manipulate products freely and perform such functions as zooming (to study tornadic activity), or screen roaming (to examine other weather features). Products can also be time-lapsed. This allows the PUP operator to extrapolate movement of features. Products may be stored locally on the PUP's hard disk, or sent to the printer for a color hard copy.

PUPs are connected to the RPG via a narrow band (ordinary telephone lines). Like other components, PUPs may be geographically separated from the host system (RDA/RPG) by many miles. A minimum of one PUP must exist to constitute a complete system. However, since the WSR-88D is designed to support several users, numerous PUPs can be configured to access a single RPG; the actual number of users varies. Each PUP's distance from their respective RPG depends solely on their geographical location. Common PUP sites include military installations, National Weather Service forecast centers, Federal Aviation Administration airport offices, and the Air Force Weather Agency (AFWA) to name a few. PUP hardware includes the following:



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Figure 2-29.—WSR-88D Principal User Processor (PUP).

- Two 19" color/graphic monitors that are used to display products in full or 1/4 screen mode.
- A graphic tablet and "puck" that are the primary input devices used to make product selections or request actions of the PUP processor. The graphic tablet's surface is flat and is organized as color-coded work areas. The puck is a mouse-like device that acts as a hand-held pointer to invoke desired processor commands.
- A color/graphics printer that provides hard copies on demand.
- A processor that computes or executes user commands (such as zooming, roaming, displaying maps or overlays, and implementing time-lapse loops of products). It also lets you annotate (write, or draw on) products to highlight features such as fronts. The processor also executes special product requests and

forwards them to the RPG. The PUP processor is housed in a cabinet much like the RPG but its other components resemble a computer workstation.

- A system console alphanumeric terminal that is usually located in close proximity to the PUP work space. It consists of a monochrome monitor and keyboard. The system console controls the processor by invoking hardware and software commands that affect PUP functions. It also receives alphanumeric products or messages that are not displayed on the graphic monitors.

UNIT CONTROL POSITION (UCP)

The UCP is the fourth major component required to complete a WSR-88D system. Because of its function, the UCP is regarded as the radar's central

nervous system (fig. 2-30). It ensures system integrity and reliability by monitoring and regulating each component's activities. It is used to set all adjustable parameters that determine PRF, antenna position, and all processing thresholds. The UCP is tasked with resolving operational conflicts, such as load control when overload conditions occur. The UCP executes commands via a narrowband link with the RPG (fig. 2-25). It manages both an "application" function and a "system console" function. These functions control hardware and software throughout the entire system.

Application Terminal

The applications terminal manipulates or changes **hardware** performance. It controls RDA and RPG operations including product generation, distribution, and storage. It manages internal communications and allows the isolation of individual components, or the disconnection of any user. It controls all message traffic between individual users and the UCP operator,

and may restrict system access. The UCP operator can monitor system status to ensure smooth operation.

System Console Terminal

This function primarily affects **software** performance. It provides user interface to the RPG. Specific operations include start-up and shutdown of application software, executing system diagnostics, and performing maintenance operations.

The UCP normally consists of two monochrome monitors and two keyboards (one for each function). Some UCPs, however, use only a single monitor/keyboard combination that toggles back and fourth between application and system control functions.

SYSTEM USERS

The WSR-88D is uniquely supported by a triagency program that includes the Department of

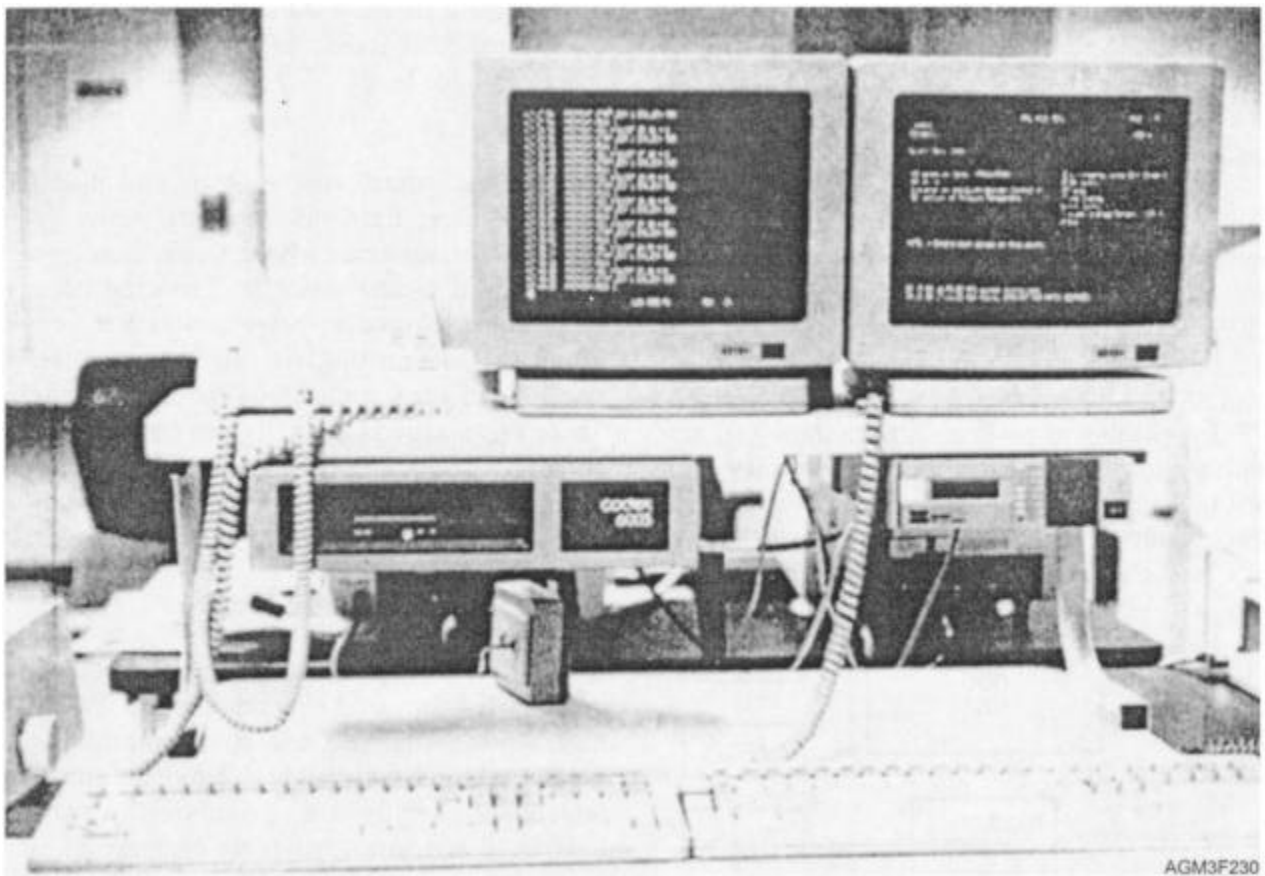


Figure 2-30.—WSR-88D Unit Control Position (UCP).

Commerce (National Weather Service), the Department of Defense (Navy/Marine Corps/Air Force), and the Department of Transportation (Federal Aviation Administration). Day-to-day product interpretation and hardware troubleshooting support for the WSR-88D can be obtained through the Operational Support Facility (OSF) located in Norman, Oklahoma. The OSF maintains a 24-hour hotline to respond to technical problems and questions that may arise while operating any component of the WSR-88D. A Naval Oceanographic Component has been assigned by the Naval Oceanographic Office to act as a liaison representative, and to specifically assist any Navy/Marine Corps activity that has a WSR-88D PUP.

It would be helpful to know the different users of the WSR-88D and how they interface with one another. Let's begin by defining all WSR-88D system users (fig. 2-31).

Principal Users

Principal users of the WSR-88D are the National Weather Service (NWS), the Department of Defense (DOD), the Federal Aviation Administration (FAA), and the subagencies they represent. Principal users can be further classified by their mode of access to the RPG. Every principal user needs a PUP to access the RPG (except PUES).

Associated Principal Users (APUPs)

An associated principal user is the priority customer supported by each system. Most Navy and Marine Corps weather offices are APUP sites. APUPs gain RPG access through a dedicated narrowband link (phone lines) and generally reside within 100 nmi of the host RDA. APUPs may request any product which the RPG is capable of producing, even those that are unavailable to other principal users. They may also request the creation of unique products, even if such requests result in increased RPG workload. While APUPs are connected via dedicated link, they're

furnished with the option to dial-in via commercial telephone lines. This enables continued receipt of products in emergency (backup) situations. APUPs exercising this option lose their "associated" status and become "non-associated" user (NAPUP).

Non-associated Principal Users (NAPUPs)

Non-associated principal users are identified as customers that dial-in for access. NAPUPs experience more restrictions than an APUP would. NAPUPs cannot request specialty products, nor can they increase RPG workload in any fashion. In fact, even routine products, maps, and overlays might be unavailable to NAPUPs (restrictions vary from system to system).

Principal Users, External Sources (PUES)

PUES are defined as principal users who access RPGs through nonstandard means. In other words, they do not use a PUP to interface with the RPG. The AFWA is only one of many PUES. The AFWA is a primary user that requires access to hundreds of radars each hour. Its mission is to mass-produce charts for DOD weather stations around the globe. In this example, the customer's own computer meets their needs more efficiently than a PUP would. All PUES are granted RPG access through reserved ports on a space available basis.

External Users

"External users" consist of anyone other than a principal user. External users are normally non-governmental agencies who are authorized access to WSR-88D data and products. These agencies may include news media, private weather services, broadcast meteorologists, airlines, universities, aviation facilities, commercial contractors, and more. These organizations generally pay for dial-in access, and their product selection is severely limited. Specialty products are unavailable to external users and cannot be requested.

SYSTEM COMMUNICATIONS

Good communications is the backbone of any complicated computer network and the WSR-88D is no exception. The WSR-88D communications system consists of two bands that fuse individual components into one efficiently run operation. The two bands (wideband and narrowband) are designed to quickly route data and products between components and users.

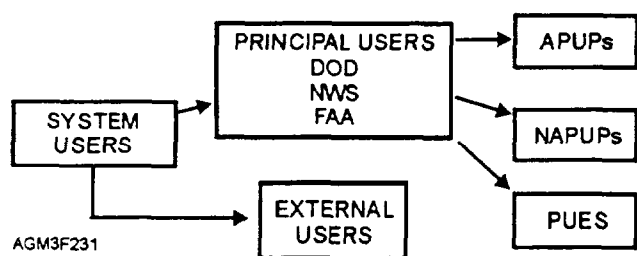


Figure 2-31.—WSR-88D system users.